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Thermotropism

Botany

A. M.

1907

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THERMOTROPISM

BY

LOIS IRENE BURWASH, A. B. 1906

**THESIS FOR
THE DEGREE OF MASTER OF ARTS
IN BOTANY**

**IN THE
GRADUATE SCHOOL
OF THE
UNIVERSITY OF ILLINOIS**

1907

UNIVERSITY OF ILLINOIS

May 31, 1907.

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Lois Irene Burwash

ENTITLED Thermotropism

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Master of Arts

APPROVED:

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Botany

101861

Our knowledge of the thermotropic response of the plant is at present very limited and depends chiefly upon the observations of Stahl ('84) on Myxomycetes, of Wortmann ('83 and '85) and of Klercker ('91) on the roots and shoots of phanerogams.

More recently Steyer ('01), at the suggestion of Pfeffer, again studied Phycomyces and finds that it does not respond to unilateral temperature as described by Wortmann. The results of Wortmann are not due to a temperature response, as Steyer points out, but rather to the response of light of unequal intensities striking the seedlings from three large windows.

Wortmann used two methods of experimentation, depending on whether the seedlings were to be subjected to radiant or conducted heat. For testing the response to radiant heat the seedlings were placed at varying distances from an iron plate covered with soot on the side toward the seedlings and heated by small gas jets on the opposite side. For testing the response to conducted heat he used a box divided into two compartments by a diathermous partition. In one of these compartments filled with sawdust the seeds were imbedded; through the other there was passed a constant current of cold water. The wall of the compartment containing the seedlings opposite the cold water chamber was heated by gas jets. The apparatus A I used was a modification of that used by Wortmann. In each end of a large wooden case 2 ft. 6 in. by 1 ft. 8 in. there was fitted a copper reservoir. Through one of the reservoirs there flowed a constant stream of cold water (18° C). Through the other there flowed a constant stream of hot

1
1000
1000
1000



water (65° C). Between these reservoirs the trays containing the seedlings were placed. The trays were without ends so that the sawdust in which the seedlings were imbedded came in immediate contact with the metal of the reservoir for experiments on conducted heat. Similar reservoirs with the walls directed towards the tray of seedlings "sooted" were used in the experiments on radiant heat. The degree of heat could be readily regulated and maintained constant by means of a thermoregulator. Since the source of heat was thus maintained constant the seedlings at varying distances from the respective reservoirs were subjected to different though constant temperatures. The tray with the seedlings fitted snugly between the two reservoirs was 17 inches long and 13 inches wide. After soaking the seeds 24 hours they were planted in sawdust or sphagnum in rows one inch apart and ten seeds in a row. By this method ten seedlings were in every case subjected to the same temperature.

Apparatus B

A rusty oven was used, which was heated by means of a gas flame. After the desired temperatures were reached the box containing the seedlings was placed near the oven on horizontal iron bars, so that the first row of seedlings was 1 1/2 inches from the oven. The temperature over the seedlings ranges from 25° C to 52° C.

(+) = position.

(-) = negative.

(x) = killed by heat.

(±) = neither positive nor negative.

(0) = no germination.

(temp.) = temperature.

A

The Effect of Radiant Heat on the Shoots of Corn

Experiment 1 - Feb. 25, 1907

The seedlings were allowed to develop in the tray in a dark room at 20° C until the shoot was 2 cm. above the sawdust. The tray was then placed between the reservoirs as above described. The range of temperature was from 20° C to 44° C. The results after 7 1.2 hrs. are given in Table I. a.

Experiment 2 - March 14, 1907

The seedlings were prepared as in Experiment I. The range of temperature was 22° C to 44° C. The results after 7 hrs. are given in Table II. a.

Experiment 3 - March 21, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 22.1° C to 43° C. The results after 7 1.4 hrs. are given in Table III. a.

Experiment 4 - March 28, 1907

The seedlings were prepared as in Experiment 1, except that they were grown in sphagnum instead of sawdust. The range of temperature was from 24° C to 48° C. The results after 7 1.2 hrs. are given in Table IV. a.

Experiment 5 - Feb. 18, 1907

The seedlings were prepared as in Experiment 1. The apparatus (Apparatus B) was so placed that weak light reached the shoots of some of the seedlings in the tray. The markedly negative curves obtained in the heated end of the tray are due to weak unilateral light. The results after 7 1.4 hrs. are given in Table V. a.

Experiment 6 - April 22, 1907

The seedlings were prepared as in Experiment 1, except that they were grown in sphagnum instead of sawdust. The range of temperature was from 24° C to 43° C. The results after 7 hours are as in previous experiments - there are no definite curves in any direction at the different temperatures.

The following table will show that the reaction of the shoots of corn to temperature was by no means definitely marked.

No. of seedlings	+	-	±	0	temp.
40	11	5	21	3	44° C
40	9	3	21	7	30° C
40	14	3	15	8	23° C

B

The Effect of Conducted Heat on the Roots of Corn

In the experiment on the effect of conducted heat on the roots of corn the same apparatus (A) was used as for the experiment in the preceeding section on the effect of radiant heat on the shoot of corn. However, special care was taken to insure intimate contact of the sawdust of the tray in which the seedlings were imbedded with the copper walls of the reservoirs.

Experiment 1 - Jan. 11, 1907

The seeds were imbedded in sawdust in rows, two seeds in each row. When the roots were from 2 to 2 1.2 cm. long, the tray was placed in position between the copper reservoirs and the sawdust brought into intimate contact with them. The range of temperature in the sawdust at the depth of the root tip was from 21° C to 43° C. The results after 10 hours are given in Table I. b.

Experiment 2 - Jan. 24, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 19° C to 46° C. The results after 8 1.2 hrs. are given in Table II. b.

Experiment 3 - Jan. 30, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 20° C to 44° C. The results after 8 hrs. are given in Table III. b.

Experiment 4 - Feb. 4, 1907

The seeds were imbedded in sawdust in rows as in the experiments on the shoots in section A. When the roots were from 2 to 2 1.2 cm. long the tray was placed in position between the copper reservoirs and the sawdust brought into intimate contact with them. The range of temperature in the sawdust at the depth of the root tip was from 19° C to 45° C. The results after 7 1.2 hrs. are given in Table IV. b.

Experiment 5 - Feb. 9, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 21° C to 42+° C. The results after 8 hrs. are given in Table V. b.

The following table will show that the reaction of the roots of corn to temperature was by no means definitely marked.

No. of seedlings.	+	-	±	0	x	temp.
26	5	6	12	1	2	43+° C
26	2	8	11	5		30° C
26	4	8	13	1		23° C

C

The Effect of Radiant Heat on the Shoot of the Pea

Experiment 1 - April 7, 1907

The seedlings were prepared as described in the experiments on the shoots of corn. When the shoots were about 3 cm. high the tray was placed almost in contact with the wall of a sheet-iron oven heated to a high temperature. The temperature ranged from 25° C in the row farthest from the oven to 52° C in the row next the oven. The results after 7 1.2 hrs. are given in Table I. c. It will be noticed that the temperature in the rows next the oven killed or seriously injured the shoots.

Experiment 2 - April 9, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 26° C to 41° C. After 7 hrs. the shoots showed no definite curves in any direction at the different temperatures.

Experiment 3 - April 12, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 25° C to 53° C. After 7 1.2 hrs. the shoots showed no definite curves in any direction at the different temperatures.

Experiment 4 - April 17, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 25° C to 43° C. The results after 7 1.2 hrs. gave no definite curve in any direction.

Experiment 5 - April 18 & 19, 1907

The seedlings were prepared as in Experiment 1. The range of temperature was from 24° C to 40° C. No response was noted after 7 hrs. The next day, April 19, the experiment was repeated using the same seedlings with the same results. No response was obtained by heating the second day.

Summarizing the effect of radiant heat on the shoots of Indian Corn and of the Pea, we note that the temperature varied between extremes fully as wide as those for which Wortmann noted a thermotropic response. It is further to be noted that the gradation of temperature between the two extremes is sufficiently small not to overlook the critical point at which reaction occurs. This can be readily seen by examining the table that follows and by noting the temperature maintained for the different rows of seedlings during the period of experimentation.

Row I.	2 1/2	cm.	from reservoir	43° C.
Row IV.	10	"	"	33° C.
Row VI.	15	"	"	28° C.
Row X.	25	"	"	27° C.
Row XIII.	32 1/2	"	"	26° C.
Row XV.	37 1/2	"	"	25° C.

Temp. of room - 19+° C.

Again the results of Wortmann were based in my opinion on the behavior of by far too small a number of seedlings. In the experiment here recorded large numbers of seedlings were subjected to the same conditions in each experiment, and the experiments were repeated a sufficient number of times to exclude all error due to environmental conditions. Thus in the experiments on the shoot of corn the number of seedlings used was as follows.

Experiment I.	- 170
"	II. - 150
"	III. - 150
"	IV. - 150
"	V. - 170
"	VI. - <u>150</u>
Total -	940

Wortmann in his experiments used only 11 seedlings of which number 9 reacted thermotropically, and two did not respond. This response as my experiments and those of Steyer clearly demonstrate was due to unilateral light rather than to unilatera real heat.

In the experiments on the root of Corn the number of seedlings used was as follows:

Experiment I.	-	28
"	II.	- 32
"	III.	- 28
"	IV.	- 160
"	V.	- <u>170</u>
Total	-	368

Wortmann in his experiments used only 30 seedlings, of which number 15 reacted negatively, 8 positively and the remaining 7 were left straight.

In the experiment on the shoots of the Pea the number of seedlings used was as follows:

Experiment I.	-	150
"	II.	- 150
"	III.	- 150
"	IV.	- 150
"	V.	- 150
"	VI.	- 150
"	VII.	- <u>150</u>
Total	-	1050

Wortmann in his experiments used only 43 seedlings, of which number 14 did not respond, 14 were positively and 15 negatively thermotropic.

If the results of the numerous experiments on the effect of conducted heat be brought together we notice no thermotropic response of the root of corn. The same results are true of the effect of radiant heat upon the shoots of corn and peas. These are contrary to the results obtained by Wortmann.

Reaction of the Shoot of Corn to Temperature

Table I. a

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	±	-	0	±	±	0	±	±	-	±	44° C
2	0	0	±	0	±	±	0	±	±	0	
3	+	±	±	±	±	±	0	±	±	0	30° C
4	+	+	+	+	+	0	±	+	+	+	
5	0	0	±	±	±	+	+	±	0	0	28° C
6	±	+	+	+	±	+	±	+	+	0	
7	+	+	+	+	+	+	+	±	0	+	
8	±	0	±	±	+	0	±	±	+	+	
9	0	0	+	±	+	+	0	+	±	+	26° C
10	+	±	+	0	+	0	+	+	+	+	
11	0	±	+	+	+	±	±	+	±	+	
12	0	+	+	0	±	0	+	+	0	+	
13	0	+	+	+	±	0	±	±	+	+	23° C
14	+	+	±	+	0	±	+	±	±	+	
15	+	+	0	0	±	±	+	+	0	+	
16	0	0	±	±	±	+	±	+	0	+	
17	±	+	±	+	+	±	+	+	+	+	20° C

Total no. seeds - 170.

Grown in sawdust. Apparatus A used.

Temp. cold H₂O = 18° C.

Temp. hot H₂O = 65° C.

Feb. 25, 1907.

Reaction of the Shoot of Corn to Temperature

Table II. a

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	+	±	+	±	+	+	+	±	±	±	44° C
2	±	±	±	+	+	±	±	+	±	±	
3	+	+	±	+	-	-	+	+	+	±	30.4° C
4	0	±	-	+	+	+	+	±	±	±	
5	+	+	±	±	±	0	±	-	±	±	
6	+	-	+	-	-	+	±	+	+	+	27° C
7	±	+	±	±	+	+	+	±	±	-	
8	+	±	0	±	-	+	0	+	±	±	
9	+	±	±	+	-	±	+	+	+	±	25.3° C
10	±	±	+	-	+	+	0	-	0	±	
11	±	±	+	±	-	-	±	-	+	±	
12	+	-	+	+	+	-	+	±	±	0	23° C
13	+	-	+	+	+	±	+	-	0	+	
14	-	+	+	-	±	±	+	+	±	+	
15	+	+	+	-	-	+	±	0	±	0	22° C

Total no. seeds - 150

Grown in sawdust.

Apparatus A used.

March 14, 1907.

Reaction of the Shoot of Corn to Temperature

Table III. a

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	+	±	0	±	+	±	+	±	+	±	43° C
2	±	+	±	-	0	±	-	-	±	±	
3	±	±	+	±	±	-	-	-	±	+	35° C
4	+	±	+	0	±	±	+	±	0	+	
5	+	±	+	0	-	±	±	±	±	±	
6	±	±	+	±	±	±	±	0	0	±	31.5° C
7	±	±	±	+	±	±	-	±	±	±	
8	±	+	+	±	±	±	±	±	+	+	28.2° C
9	±	+	-	±	±	0	+	+	+	0	
10	+	±	+	±	±	±	±	±	±	+	26.4° C
11	0	±	±	+	±	+	0	+	+	0	
12	0	±	±	±	+	±	±	0	±	+	23.2° C
13	±	+	+	+	+	+	+	+	±	+	
14	+	+	+	+	+	+	+	+	±	±	22.6° C
15	±	+	±	+	±	+	±	+	±	+	22.1° C

Total no. seeds - 150.

Grown in sphagnum.

Apparatus A used.

March 21, 1907.

Reaction of the Shoot of Corn to Temperature

Table IV. a

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	-	±	-	±	-	±	+	±	±	-	48° C
2	±	±	-	+	+	±	±	-	-	±	
3	±	-	±	±	±	±	±	±	±	0	33° C
4	±	±	+	0	±	±	±	+	+	+	
5	0	0	±	-	+	±	±	±	0	0	
6	0	-	+	-	-	0	±	±	0	±	
7	±	±	+	+	-	±	±	+	-	0	
8	±	±	±	-	±	0	+	±	0	±	32° C
9	±	+	0	±	0	0	±	0	±	0	
10	-	±	0	±	0	0	+	-	±	0	
11	±	0	0	±	-	±	-	-	0	±	28° C
12	±	0	+	-	±	±	±	0	0	+	
13	+	0	-	+	+	±	±	±	0	±	
14	0	-	+	0	0	0	+	-	-	+	25° C
15	±	0	±	+	+	-	±	±	0	0	24° C

Total no. seeds - 150.

Planted in sphagnum.

Apparatus A used.

March 28, 1907.

Reaction of the Shoot of Corn to Temperature

Table V. a

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	0	-	-	±	-	±	±	-	0	-	42+° C
2	-	-	-	-	±	±	0	+	-	-	
3	0	-	-	-	0	0	±	-	-	0	30° C
4	-	0	0	-	0	0	±	0	-	-	
5	±	-	±	0	-	±	±	0	-	-	
6	-	-	-	±	±	±	+	±	±	0	27.8° C
7	-	±	±	0	-	-	±	±	±	0	
8	0	0	-	0	-	±	±	0	±	-	
9	0	-	-	-	-	±	0	±	0	0	25.5° C
10	0	±	0	0	-	0	+	±	±	0	
11	-	0	-	±	±	±	±	±	±	±	
12	0	±	±	±	±	±	0	±	±	-	
13	0	±	-	-	±	0	0	±	±	0	23° C
14	0	±	0	±	±	±	±	±	-	±	
15	±	±	±	±	±	±	0	±	±	±	
16	0	0	±	0	±	±	±	0	±	0	22° C
17	±	±	±	±	±	0	±	±	0	±	21° C

Total no. seeds - 170.

Apparatus A used.

Planted in sawdust.

Feb. 18, 1907.

Reaction of the Root of Corn to Temperature

Table I. b

No. seeds in each row	1	2	Temp.
Row			
1	x	x	43° C
2	±	±	30.8° C
3	-	-	
4	-	-	27° C
5	±	±	
6	±	±	
7	-	±	
8	-	±	
9	±	±	
10	±	±	23° C
11	±	0	
12	±	±	22° C
13	-	±	
14	±	±	21° C

Total no. seeds - 28.

Apparatus A used.

Jan. 11, 1907.

Reaction of the Root of Corn to Temperature

Table II. b

No. seeds in each row	1	2	Temp.
Row			
1	±	0	46° C
2	-	-	32.7° C
3	0	-	
4	±	±	
5	±	±	30° C
6	0	0	
7	±	±	
8	0	±	
9	±	0	24° C
10	±	±	
11	±	±	23+° C
12	±	+	
13	±	±	21° C
14	±	0	
15	±	-	
16	±	±	19° C

Total no. seeds - 32.

Apparatus A used.

Jan. 24, 1907.

Reaction of the Root of Corn to Temperature

Table III. b

No. seeds in each row	1	2	Temp.
Row			
1	±	±	44° C
2	±	-	29.5° C
3	-	-	27.6° C
4	±	+	27° C
5	+	+	
6	+	+	
7	±	±	23.9° C
8	-	+	23.6° C
9	-	-	
10	0	±	22° C
11	-	±	
12	-	-	21.6° C
13	±	±	
14	+	+	20° C

Total no. seeds - 28.

Apparatus A used.

Jan. 30, 1907.

Reaction of the Root of Corn to Temperature

Table IV. b

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	±	±	±	±	+	+	-	-	-	-	45° C
2	-	-	-	-	-	+	+	±	±	±	31° C
3	±	±	-	-	-	-	-	+	±	±	
4	-	-	±	±	+	+	±	±	±	±	28° C
5	+	+	±	±	±	±	-	-	±	±	
6	+	+	+	+	+	+	±	±	±	-	
7	-	-	-	-	-	0	±	+	+	+	
8	-	-	-	±	±	±	±	+	±	±	
9	-	-	-	-	0	+	+	±	±	±	23.5° C
10	±	±	±	±	+	+	+	-	-	-	
11	±	±	±	±	±	±	±	-	+	+	
12	-	-	±	±	+	±	±	±	±	0	
13	+	+	+	+	+	+	±	-	-	-	
14	+	+	+	+	0	-	-	-	±	±	
15	-	-	-	-	-	-	0	+	+	+	
16	-	-	-	-	±	±	0	+	+	+	19° C

Total no. seeds - 160.

Apparatus A used.

Feb. 4, 1907.

Reaction of the Root of Corn to Temperature

Table V. h

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	+	+	+	-	-	±	±	±	±	±	42 +° C
2	+	+	+	-	-	-	±	±	±	±	
3	-	-	±	±	±	0	0	0	0	0	
4	+	-	-	-	±	±	±	±	±	0	30° C
5	+	+	+	+	+	-	±	±	±	0	
6	+	+	-	-	-	±	±	±	±	±	
7	+	+	-	-	±	±	±	±	±	±	27.8° C
8	-	-	±	±	±	±	±	±	±	±	
9	+	+	+	+	+	+	±	±	±	±	
10	+	+	+	+	+	±	±	±	±	±	25.5° C
11	+	+	±	0	0	0	0	0	0	0	
12	+	-	-	±	±	±	±	±	±	0	
13	+	-	-	-	±	±	±	±	±	±	23° C
14	+	+	-	-	-	±	±	±	±	±	
15	-	±	±	±	±	±	±	±	±	0	
16	-	-	±	±	±	±	±	±	±	±	21.1° C
17	-	±	±	±	±	±	±	±	±	±	

Total no. seeds - 170.

Apparatus A used.

Feb. 9, 1907.

Reaction of the Shoot of the Pea to Temperature

Table I. c

No. seeds in each row	1	2	3	4	5	6	7	8	9	10	Temp.
Row											
1	-	x	x	x	x	x	x	x	x	x	52° C
2	-	-	-	±	-	x	x	x	x	x	
3	-	-	-	-	x	0	-	-	-	0	43° C
4	-	-	-	-	-	-	-	-	-	-	37° C
5	-	0	-	-	±	-	-	±	±	-	
6	±	±	0	+	-	-	-	0	0	-	29+° C
7	-	±	-	0	-	±	±	-	-	-	29° C
8	-	±	±	-	±	-	±	-	-	±	
9	±	±	-	±	-	-	±	+	±	0	
10	±	-	±	±	±	+	±	±	0	+	26.3° C
11	±	±	-	±	+	±	±	±	-	0	26+° C
12	±	+	+	±	-	±	0	±	-	±	26° C
13	+	0	±	±	±	-	±	±	±	±)	
14	0	±	-	+	±	-	+	0	+	-)	25+° C
15	±	±	+	±	±	±	0	±	-	0	25° C

Total no. seeds - 150.

Apparatus B used.

Results due to light.

April 7, 1907.

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